UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 601

Joint Contribution from the Bureau of Plant Industry, WM. A. TAYLOR, Chief, and the Bureau of Markets, CHARLES J. BRAND, Chief

Washington, D. C. ▼ December 21, 1917

THE HANDLING AND PRECOOLING OF FLORIDA LETTUCE AND CELERY

By

H. J. RAMSEY, Pomologist in Charge of Fruit and Vegetable Handling and Storage Investigations, and E. L. MARKELL, Scientific Assistant, Office of Horticultural and Pomological Investigations

CONTENTS

WASHINGTON
GOVERNMENT PRINTING OFFICE
1917

The investigations upon which this bulletin is based were made in the fruit and vegetable handling and storage division of the Office of Horticultural and Pomological Investigations of the Bureau of Plant Industry. The fruit and vegetable handling, transportation, and storage investigations of the Department of Agriculture are now prosecuted jointly and cooperatively by the Bureau of Plant Industry and the Bureau of Markets.

Actively associated in the prosecution of these investigations were H. C. Thompson, horticulturist; S. J. Dennis, technologist; G. W. Dewey, C. L. Dyer, J. F. Fernald, G. L. Fischer, W. E. Mosher, W. C. Quick, and E. D. Vosbury, of the Office of Horticultural and Pomological Investigations, and K. B. Lewis, formerly of that office.

This bulletin is of special interest to all growers and shippers of lettuce and celery in the Gulf States, particularly Florida, and of general interest to truck growers in other parts of the country. It also contains information of value to railroad and steamship lines handling these products, to cold-storage men, and to receivers of lettuce and celery from Florida and the Gulf States.

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CONTENTS.

PREVENTING DECAY IN LETTUCE AND CELERY.

The lettuce and celery crops of Florida contribute annually about one and one-half million dollars to the incomes of the truck growers in that State. About 4,000 acres now are devoted to the culture of these crops, and this area is being increased constantly. The expansion of the celery industry has been especially rapid. Starting practically within the last decade, Florida is now one of the leading celery-producing States of the Union. The census of 1909 shows that Florida had then only 825 acres of celery. By 1913 the plantings had increased to 1,280 acres,[1] an increase of 55 per cent in four years.

The diseases and insect enemies to which most cultivated plants are susceptible quickly appear in new localities where the plants are introduced. Though they may not be apparent at first, when climatic and other conditions are favorable these enemies may so

[1] Agricultural statistics for the years 1913–14. *In* 13th Bien. Rpt. Dept. Agr. Fla., Div. Agr. and Immigr., 1913–14, p. 276. [1915.]

increase from year to year that the crops can not be grown successfully. Oftentimes the problems that have confronted the lettuce and celery growers during the past few years have been due to such conditions. Heavy losses have resulted from decay not only in the field, but in apparently sound produce while in transit. This condition made it seem desirable to undertake a series of investigations with a view to determining whether some practical commercial method could be devised for reducing the losses that occur from the time the products leave the field until they reach the consumer. The Bureau of Plant Industry has conducted handling and precooling investigations with several crops in other sections of the country, and similar investigations were begun with lettuce and celery in Florida in the autumn of 1913. During the season of 1913–14 particular attention was paid to the lettuce crop, and therefore this will be discussed first.

LETTUCE-HANDLING INVESTIGATIONS.

NATURE OF THE PROBLEM.

The experimental work was done in the vicinity of Palmetto, in Manatee County, the center of one of the largest lettuce-producing sections of Florida. Lettuce has been grown there on a commercial scale for 15 years or more. In a great many cases it was found that lettuce had been grown year after year on the same land. As a result, practically all the cultivated fields in this section are infected with disease-producing organisms.

Probably the most dangerous enemy of the lettuce crop is a fungus disease (*Sclerotinia libertiana*),[1] commonly known as lettuce drop, which causes tremendous losses yearly. Under conditions favorable to the growth of the fungus, whole fields sometimes are destroyed within a short period of time. The first indication of the presence of the disease is a slightly wilted appearance of the lower leaves. The drop produces a discolored or watery area on the under sides of the infected leaves, and this is followed quickly by the appearance of white threadlike masses. The disease spreads rapidly throughout the head, causing it to collapse into a slimy mass. Infected leaves often may be found on heads that appear to be perfectly healthy, and sometimes it is impossible to find in a field a single plant that does not show some signs of infection. Figure 1 shows a field in which practically all the plants are affected with the drop. The wilted appearance of these plants as compared with those in the disease-free field shown in figure 2 is very marked.

The general practice of most growers in preparing the lettuce for market is to cut off all plants close to the ground. The worst of the

[1] Burger, O. F. Lettuce drop. Fla. Agr. Exp. Sta. Bul. 116, p. 27–32, 3 fig. [1913.]

bottom leaves are then trimmed off, and the head is placed in the hamper or crate. The sole purpose of the trimming is to improve the appearance of the head, and often little or no attention is given to the presence of signs of disease. The hampers are packed tightly, the lettuce heads forming a compact mass that cools rather slowly. In addition, the hampers are loaded in the cars in such a manner as greatly to interfere with the natural air circulation. Figure 3 illustrates the usual arrangement of the load. The hampers are placed horizontally, with the tops and bottoms alternating. By this arrangement the hampers are fitted tightly together and the pressure is so distributed that they do not break readily. As usually loaded into

FIG. 1.—A lettuce field badly infested with the drop disease, from which no lettuce heads have been harvested.

the cars the hampers are four layers high. This leaves ample air space above the load, but the hampers are so close together that the circulation of air between them is very slow, and those in the center of the car retain the field heat for a long time. Most plant diseases develop rapidly at the higher temperatures, and this is particularly the case with lettuce drop. As a result, a great deal of lettuce has arrived on the market in unsound condition.

OUTLINE OF EXPERIMENTS IN 1913-14.

CAREFUL CUTTING.

In order to determine the effect of greater care in preparing lettuce for shipment, various methods of cutting were tested in these investigations. It seemed evident from the start that the infection occurred

mainly through the lower leaves, which rest on the ground. Therefore the lettuce was cut at a point just above these leaves. This method left the three or four under leaves untouched on the ground. If one or two of the leaves on the head showed signs of decay they were pulled off. If a large number of leaves were diseased or if the main stalk showed signs of disease, the head was discarded. Only lettuce that appeared entirely free from disease was included in these carefully cut lots. Figure 4 is a fair representation of the appearance of the lettuce when cut by either method. The commercially cut lettuce is dirty and shows diseased areas on the lower leaves,

FIG. 2.—A field of healthy lettuce, showing the condition of the plants at harvest time.

whereas that carefully cut is clean, attractive, and free from disease. The carefully cut lettuce was packed in accordance with commercial methods, and a similar lot, cut and handled throughout commercially, was obtained from the same field at the same time for purposes of comparison.

PRECOOLING.

The lots obtained each day were divided into two parts: Half of the carefully cut lettuce and half of that commercially cut were precooled, and comparable lots were placed under regular refrigeration.

The precooling was done by means of the portable precooling plant of the Office of Horticultural and Pomological Investigations. This

plant consists of a complete 12-ton refrigerating outfit installed in a freight car. Ammonia expansion coils in a well-insulated compartment at one end of the car furnished as low a temperature as was desired, and a 45-inch fan forced the necessary circulation of air. Refrigerator cars were loaded with lettuce in the usual manner and brought to the precooling plant, where cold air was then blown through the car, entering at one of the bunkers and going out at the other. Twelve electrical thermometers were distributed through the load. One thermometer was placed in the lettuce near the outside of the head end of the package and one in the center in each of six

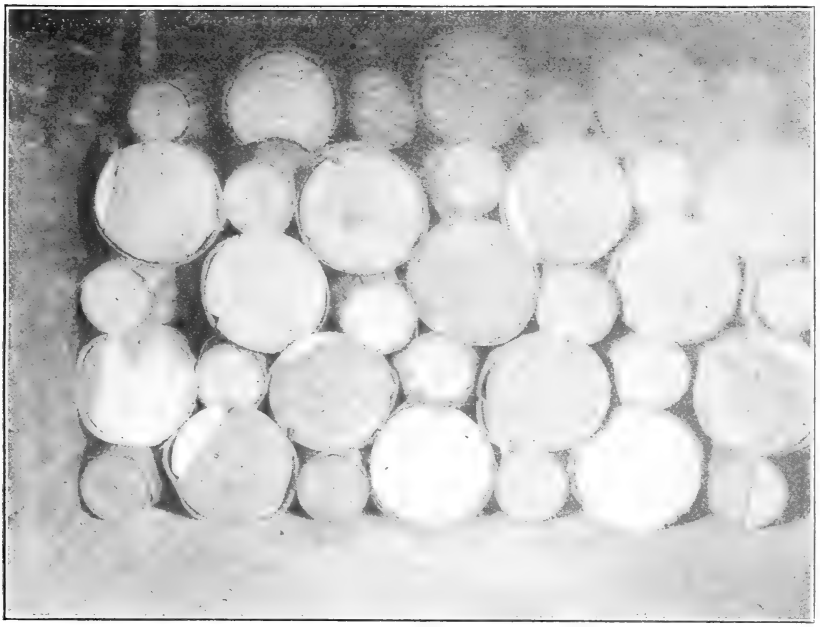

FIG. 3.—Hampers of lettuce loaded in a refrigerator car with very little space between the hampers for circulation of air.

hampers, which were located as follows: Two hampers at each end of the car, next to the bunkers, placed midway between the side walls, one at the top and one at the bottom of the load. The other two hampers were located as near the center of the car as possible, one at the top and one at the bottom of the load. The thermometers were connected with a main cable, which extended through the side ventilators to the outside of the car and provided a means of accurately determining the temperature at any time without opening the doors. The precooling was commenced as soon as possible after the cars were loaded and continued until the average temperature of all

the thermometers was about 40° F. It has been determined that this point is about as low as the ice in the bunkers will hold the load.

TREATMENT OF EXPERIMENTAL LOTS.

As has been stated, the precooled car contained an experimental lot consisting of an equal number of hampers of lettuce carefully cut and commercially cut from the same field at the same time. An exactly similar lot was shipped at the same time in a refrigerator car that was not precooled. The two cars went to the same market, in most cases to New York City, where a representative of the Department of Agriculture inspected them upon their arrival and again three days later.

Comparable lots, both precooled and nonprecooled, were held at Palmetto in an iced refrigerator car and kept under approximate

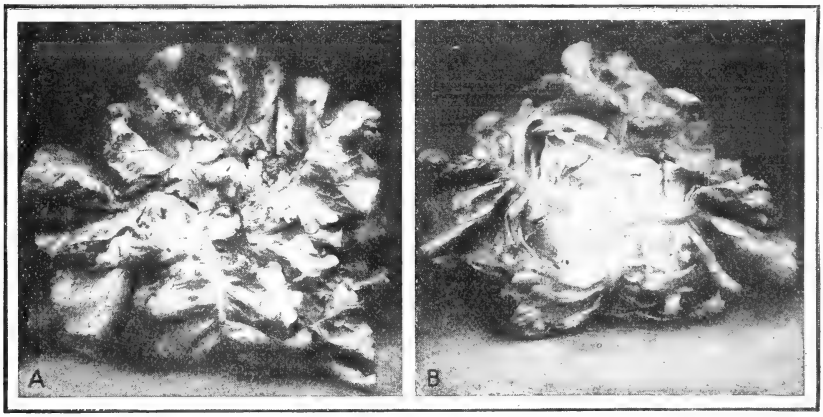

FIG. 4.—Two heads of lettuce, showing the difference in methods of cutting: *A*, Commercially cut *B*, carefully cut.

transit temperature conditions. It was possible to keep the temperatures in this holding car under close control, so that these lots give a good index of the effect of temperature on the development of decay. Six days after cutting—the average length of time required for the cars to reach the principal northern markets—the lettuce was removed from the holding car and inspected. It was then held at ordinary temperatures for three days and again inspected. Accurate records were kept as to the general condition of the lettuce and the amount of decay at each inspection.

RESULTS OF EXPERIMENTS IN 1913–14.

SHIPPING LOTS.

During the season of 1913–14 nine full comparable experimental lots were shipped to northern markets and 16 lots were held in Palmetto. The following tables and diagrams give a summary of

the results obtained as regards the general market condition and the amount of decay in lettuce treated in the different ways described.

The results of the inspections of experimental lots shipped to northern markets are shown in Table I.

The results recorded in Table I are represented graphically in figure 5. The open line in figure 5 represents the percentage of prime or first-class lettuce, the shaded line the percentage of marketable lettuce, and the solid line the percentage of worthless lettuce. The most striking point brought out by this diagram is the effect of careful cutting on the market condition of the lettuce. In the non-

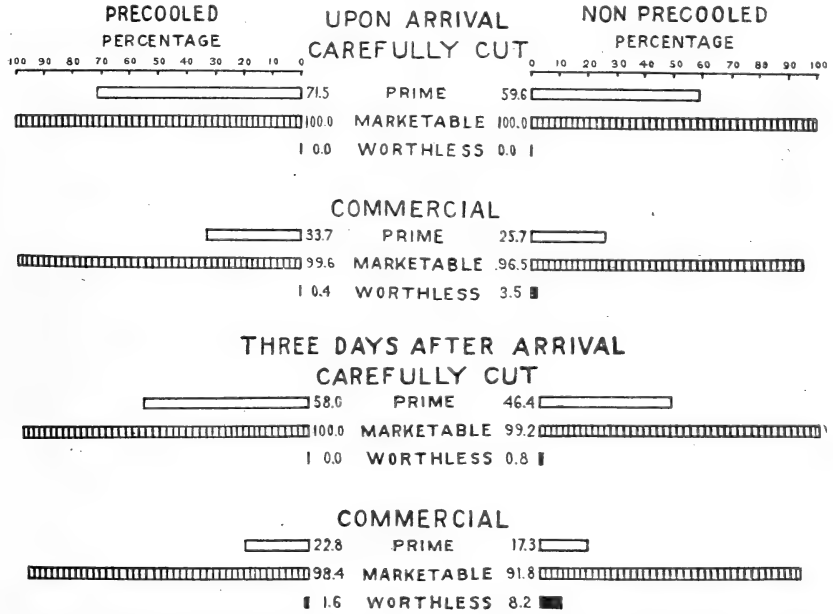

FIG. 5.—Diagram illustrating the percentages of prime, marketable, and worthless lettuce upon arrival at the market and three days later in precooled and in nonprecooled commercially cut and carefully cut lettuce shipped from Palmetto, Fla., season of 1913–14.

precooled series the carefully cut lettuce showed an average of 59.6 per cent in prime condition upon its arrival at the market, as compared with 25.7 per cent in the case of that commercially cut. The precooled series showed just as marked results: 71.5 per cent prime in the carefully cut, and only 33.7 per cent prime in the commercially cut lettuce. After holding for three days, the amount of first-class lettuce was considerably decreased, but in all cases the carefully cut lettuce showed over twice as much first-class lettuce as that commercially cut. The beneficial effects of precooling are well illustrated in this diagram, but are shown more strikingly in Table II.

TABLE I.—*Average market conditions of nine experimental lots of carefully cut and commercially cut lettuce shipped to northern markets during the season of 1913–14.*

Treatment.	At withdrawal.		Three days after withdrawal.	
	Carefully cut.	Commercially cut.	Carefully cut.	Commercially cut.
Nonprecooled:				
Prime heads.....per cent..	59.6	25.7	46.4	17.3
Marketable[1] heads.....do....	100	96.5	99.2	91.8
Precooled:				
Prime heads.....do....	71.5	33.7	58	22.8
Marketable heads.....do....	100	99.6	100	98.4

[1] The term "marketable" as used here includes all heads with sound hearts, even though the outer leaves were in some cases more or less decayed.

Figure 6 shows the very striking results of careful cutting. Where the nonprecooled commercially handled lettuce on the first inspection shows a total decay of 44.5 per cent, the nonprecooled carefully cut lettuce shows only 8.8 per cent of decay, or, in other words, the method of cutting that keeps the infected lower leaves out of the

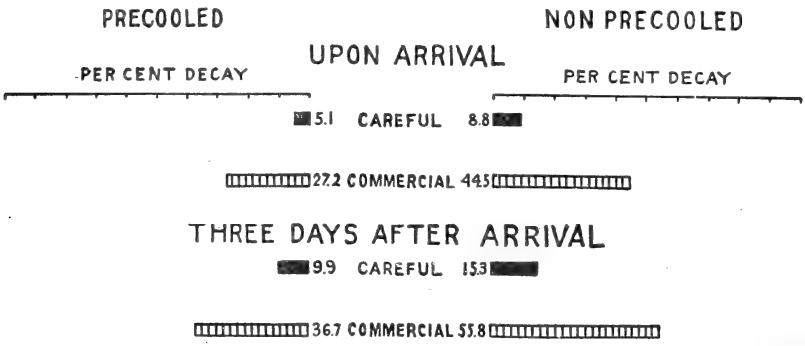

FIG. 6.—Diagram illustrating the percentages of drop decay found upon arrival at the market and three days later in precooled and in nonprecooled commercially cut and carefully cut lettuce shipped from Palmetto, Fla., in the season of 1913–14.

hamper reduces the decay four-fifths. A single glance at the diagram (fig. 6) shows the great difference between the carefully cut and commercially cut lettuce both upon arrival at the market and three days later, the short line in each case representing the decay in the carefully cut and the long line the decay in the commercially cut lots. The column on the left shows the average total decay in the precooled lots, and the column on the right the decay in the nonprecooled lots. Precooling had the greatest effect on the commercially cut lots. For example, the precooled commercially cut lettuce showed an average of 27.2 per cent decay upon arrival, in contrast to 44.5 per cent in the case of the nonprecooled. Precooling used in connection with careful cutting gives the best results, as the figures

indicate, i. e., a total decay of 5.1 per cent in the precooled carefully cut lot, as against 44.5 per cent in the nonprecooled commercially cut lettuce. As the latter is the common method of cutting and shipping lettuce, it is obvious that careful cutting and precooling eliminate a very large part of the decay that usually develops in transit.

TABLE II.—*Average percentages of decay in nine experimental lots of carefully cut and commercially cut lettuce shipped to northern markets during the season of 1913–14.*[1]

Treatment.	At withdrawal.		Three days after withdrawal.	
	Carefully cut.	Commercially cut.	Carefully cut.	Commercially cut.
Nonprecooled:				
Heads showing slight drop rot.....per cent..	7.9	24.2	11.7	30.3
Heads showing medium drop rot.....do....	.9	16.9	3.3	19.6
Heads showing complete drop rot.....do....	0	3.4	.3	5.9
Total drop rot.....do....	8.8	44.5	15.3	55.8
Precooled:				
Heads showing slight drop rot.....do....	4.7	20.6	8.5	26.8
Heads showing medium drop rot.....do....	.4	6.3	1.4	8.3
Heads showing complete drop rot.....do....	0	.3	0	1.6
Total drop rot.....do....	5.1	27.2	9.9	36.7

[1] No record of bacterial decay was obtained in these lots.

In addition to the factors recorded above, the difference in appearance of the various lots was a point of great importance in determining their market value. Figure 7 shows the general appearance of the different lots at the first inspection. In almost every case the carefully cut lots were far more attractive, not only because less decayed but also because the heads were cleaner owing to the removal of the dirty lower leaves. The lettuce in the precooled hampers was also in much better condition than that in the nonprecooled hampers. Less shriveling, crisper, brighter leaves, and a general freshness of appearance, aside from any question of decay,

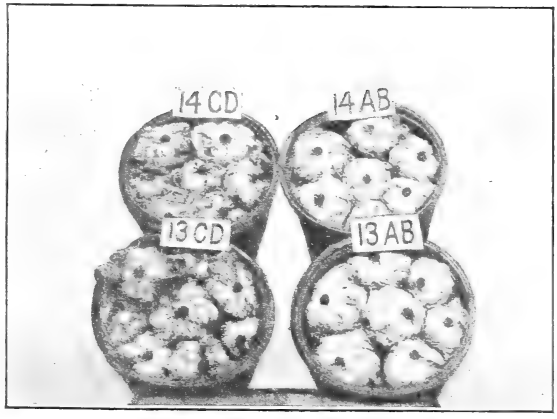

FIG. 7.—Appearance at the first inspection of lettuce handled in the following ways: Top hampers, marked "14," precooled; lower two, marked "13," not precooled; the hampers on the left, marked "CD," were commercially handled and the two on the right, marked "AB," were carefully cut.

usually made it easy to distinguish the precooled from the nonprecooled lots. The heads in the precooled hampers were usually level with the top of the hampers upon arrival at the market, while those in comparable nonprecooled hampers, because of shriveling and general decay, usually had sunk several inches below the top.

HOLDING LOTS.

The results of the inspection of sixteen experimental lots held in the refrigerator car at Palmetto are given in Tables III and IV and are shown in figures 8 and 9, respectively.

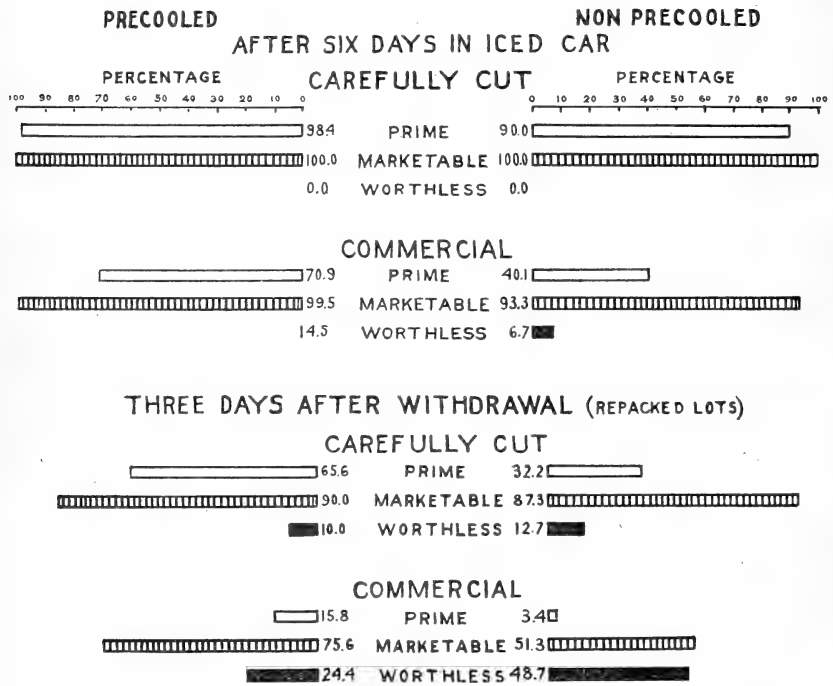

FIG. 8.—Diagram illustrating the percentages of prime, marketable, and worthless lettuce upon withdrawal from the car and three days later in precooled and in nonprecooled commercially cut and carefully cut lettuce held at Palmetto, Fla., season of 1913–14.

At the first inspection of the experimental lots held in Palmetto, one half of the lettuce in each basket was removed and inspected, the lower half being left undisturbed. The inspected half was then repacked and the whole basket held until three days later, when the two halves were inspected and recorded separately under the headings "Repacked" and "Undisturbed." This was done in order to learn what effect removal from the basket and handling while on the market had upon the lettuce. As is brought out in Table III, there is very little difference in the effect of the two methods, such difference as there is favoring the lettuce that was removed and repacked. Apparently moderate handling has little or no

harmful effect on lettuce, and, in fact the exclusion of air from the center of the packages may result in a more rapid deterioration than is the case when the heads are removed from the hampers and exposed to the air.

TABLE III.—*Average market condition of sixteen experimental lots of carefully cut and commercially cut lettuce held six days in an iced car at Palmetto, Fla., during the season of 1913–14.*

Treatment.	At withdrawal.		Three days after withdrawal.			
			Repacked.		Undisturbed.	
	Carefully cut.	Commercially cut.	Carefully cut.	Commercially cut.	Carefully cut.	Commercially cut.
Nonprecooled:						
Prime heads.....per cent..	90	40.1	32.2	3.4	31.8	4.1
Marketable heads.....do....	100	93.3	87.3	51.3	81.5	49.5
Precooled:						
Prime heads.....do....	98.4	70.9	65.6	15.8	53.8	9.4
Marketable heads.....do....	100	99.5	90	75.6	94.3	63.4

The summary of the holding experiments shown in Table III is even more striking than the summary of the shipping lots shown in Table I. The effect on the carrying quality of the lettuce of the different methods of handling employed was relatively the same in

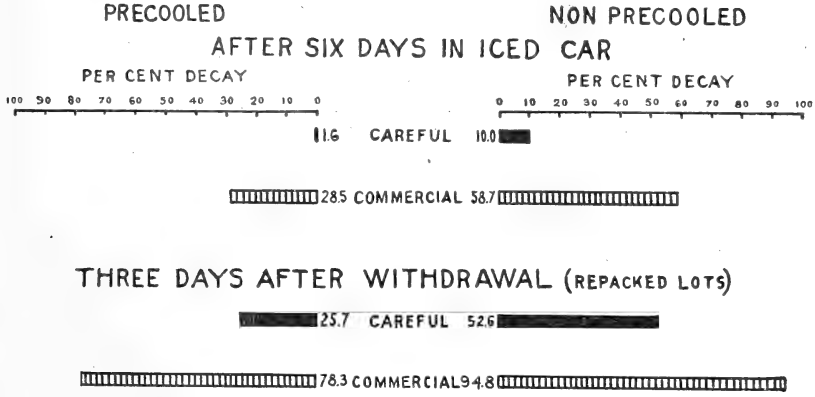

FIG. 9.—Diagram illustrating the percentages of drop decay upon withdrawal from the car and three days later in precooled and in nonprecooled commercially cut and carefully cut lettuce held at Palmetto, Fla., season of 1913–14.

both lots, but there was considerably more deterioration in the lots held at Palmetto, owing to the prevailing higher temperature. Here, again, the effect of careful cutting is shown most markedly. Over 98 per cent of the carefully cut precooled lettuce was in prime condition at the end of six days, as compared with less than 71 per cent in that commercially cut. In the nonprecooled lots the carefully cut lettuce showed an average of 90 per cent of prime heads

at the end of the 6-day holding period, while that commercially cut showed a little over 40 per cent—less than half as much.

The effect of precooling is shown best in the commercially cut lettuce. In the precooled lots practically all the lettuce was in marketable condition at the end of the 6-day holding period, and 70.9 per cent was prime, while the nonprecooled lots showed an average of 6.7 per cent of worthless lettuce and only 40.1 per cent prime. The high temperature at which the lettuce was held after its withdrawal from the refrigerator car caused it to decay very rapidly, as the lower part of figure 8 plainly indicates. The amount of worthless lettuce in the various lots three days after their withdrawal from the car is particularly worth noting. Contrasting one extreme of handling with the other, as shown in figure 8, the precooled carefully handled lettuce showed 10 per cent worthless and 65.6 per cent prime, whereas the nonprecooled commercially handled lettuce showed 48.7 per cent worthless and 3.4 per cent prime.

TABLE IV.—*Average percentages of decay in sixteen experimental lots of carefully cut and commercially cut lettuce held six days in an iced car at Palmetto, Fla., during the season of 1913–14.*

Treatment.	At withdrawal.		Three days after witddrawal.			
			Repacked.		Undisturbed.	
	Carefully cut.	Commercially cut.	Carefully cut.	Commercially cut.	Carefully cut.	Commercially cut.
Nonprecooled:						
Heads showing slight drop-rot, per cent	8.6	36.2	27.1	25.6	22.9	19.8
Heads showing bad drop-rot, per cent	1.4	22.5	25.5	69.2	30	73.8
Total drop-rot [1] ....do..	10	58.7	52.6	94.8	52.9	93.6
Heads showing bacterial rot....do..	0	2.4	7.5	5.8	7.8	9.2
Precooled:						
Heads showing slight drop-rot, per cent	1.6	24	14.6	36.5	22.6	25
Heads showing bad drop-rot, per cent	0	4.5	11.1	41.8	13.7	57.3
Total drop-rot....do..	1.6	28.5	25.7	78.3	36.3	82.3
Heads showing bacterial rot....do..	0	.7	2.6	3.4	6.4	8.5

[1] In some cases both drop and bacterial decay were found on the same head. As these diseases were recorded separately, the total of all forms of decay may appear to amount to more than 100 per cent in some instances.

A glance at Table IV and the diagram shown in figure 9 gives a convincing impression of the effect of precooling and of careful cutting upon the development of decay. In the carefully cut nonprecooled lots only 10 per cent showed serious signs of drop-rot at the first inspection, at which time the comparable commercially handled lots showed 58.7 per cent. In the carefully cut precooled lots, the drop-rot was so slight as to be of almost no commercial importance, whereas in the commercially cut nonprecooled lots more

than half of the heads showed drop decay. Three days after withdrawal from the car the precooled carefully handled lettuce showed only 25.7 per cent of drop-rot, whereas the precooled commercially handled lots showed 78.3 per cent. The nonprecooled commercially handled lettuce showed an average of 94.8 per cent of drop decay or, in other words, at the final inspection of these lots practically every head was decayed more or less seriously.

COMPARISON OF HOLDING AND SHIPPING LOTS.

The differences in the amount of decay found in the experimental shipments of lettuce inspected at the northern markets and in corresponding lots held in Palmetto are shown in Table V.

TABLE V.—*Comparison of the total percentages of decay in precooled and nonprecooled lots of carefully cut and commercially cut lettuce shipped to northern markets and in comparable lots held at Palmetto, Fla., during the season of 1913–14.*

Treatment.	At withdrawal.		Three days after withdrawal.	
	Carefully cut.	Commercially cut.	Carefully cut.	Commercially cut
Nonprecooled:				
7 holding lots.....per cent..	28.1	55.9	78.9	96.2
7 comparable shipments.....do....	20.1	39.9	30.6	53.2
Precooled:				
7 holding lots.....do....	2	9.6	22.2	50.6
7 comparable shipments.....do....	4.9	7.2	10.4	15.5

Table V shows that even at the first inspection the average decay was greater in the lettuce held in Florida than that in the lettuce shipped to northern markets, in spite of the fact that inspections at the North were made nearly two days later than those at Palmetto. At the second inspection the decay, as might be expected, was much greater in the lettuce held in Florida than in that held in the northern markets. This is undoubtedly accounted for by the difference in temperature between the two parts of the country during January and February, the months in which the experiments were carried on.

OUTLINE OF EXPERIMENTS IN 1914–15.

The experiments with lettuce, as outlined in 1913–14, were continued throughout the season of 1914–15. The weather conditions during this season were generally unfavorable, resulting in a poor quality of lettuce and very light shipments. The lettuce as a rule failed to make solid heads, and that shipped from the Palmetto section was chiefly of the leaf type. For this reason it was impossible to conduct the experiments on as large a scale as was desired. However, a number of cars were precooled, and experimental lots were again shipped to New York.

RESULTS OF EXPERIMENTS IN 1914–15.

The results obtained, which are summarized in Tables VI and VII, corroborated the results of the previous season's work recorded in Tables I and II.

TABLE VI.—*Average market condition of eighteen experimental lots of carefully cut and commercially cut lettuce shipped to New York City during the season of 1914–15.*

Treatment.	At withdrawal.		Three days after withdrawal.	
	Carefully cut.	Commercially cut.	Carefully cut.	Commercially cut.
Nonprecooled:				
Prime heads.....per cent..	94	79.8	76.9	55.6
Marketable heads.....do....	99.5	98.8	95.6	87.2
Precooled:				
Prime heads.....do....	95.3	84.8	89	71.3
Marketable heads.....do....	99.6	99.2	99.7	97.3

The results shown in figure 10 are essentially the same as those obtained the previous year, but the figures are less striking, especially in the case of the precooling experiments. The weather conditions

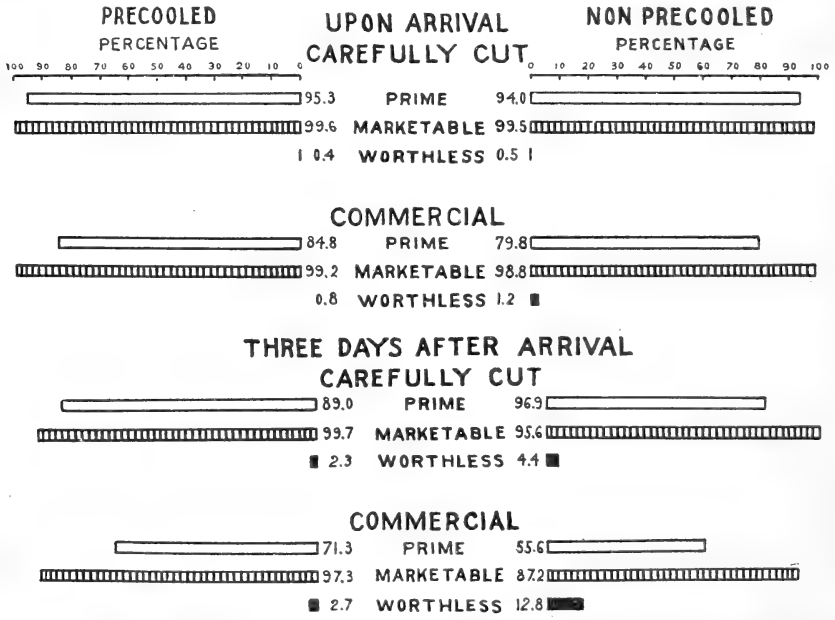

FIG. 10.—Diagram illustrating the percentages of prime, marketable, and worthless lettuce upon arrival at the market and three days later in precooled and in nonprecooled commercially cut and carefully cut lots shipped from Palmetto, Fla., season of 1914–15.

during the season were exceptional, and the temperature at the time of shipping was in most cases not high enough to render precooling imperative. In spite of this, it will be noted that all of the advantage is on the side of the precooled lettuce.

Table VII and figure 11 show the amount of decay found in the experimental lots of lettuce shipped during the season of 1914–15.

TABLE VII.—*Average percentages of decay in eighteen experimental lots of carefully cut and commercially cut lettuce shipped to New York City during the season of 1914–15.*

Treatment.	At withdrawal.		Three days after withdrawal.	
	Carefully cut.	Commercially cut.	Carefully cut.	Commercially cut.
Nonprecooled:				
Heads showing slight drop-rot.....per cent..	4.9	15.6	17	27.4
Heads showing bad drop-rot.....do....	.4	2.8	5.9	14.8
Total drop-rot.....do....	5.3	18.4	22.9	42.2
Heads showing bacterial rot.....do....	.9	3.6	2.9	5.3
Precooled:				
Heads showing slight drop-rot.....do....	2.9	10.3	7.3	18.7
Heads showing bad drop-rot.....do....	1	2	2.6	7.9
Total drop-rot.....do....	3.9	12.3	9.9	26.6
Heads showing bacterial rot.....do....	1.4	3.5	1.9	4.4

Figure 11 shows graphically the amount of decay in the lettuce upon its arrival on the market and again three days later. In both

FIG. 11.—Diagram illustrating the percentages of drop decay upon arrival at the market and three days later in precooled and in nonprecooled commercially cut and carefully cut lettuce shipped from Palmetto, Fla., season of 1914-15.

precooled and nonprecooled lots the amount of decay in the carefully cut lettuce on arrival is less than one-third that in the commercially cut lots. Three days later the carefully cut precooled lettuce showed less than one-half as much decay as that commercially cut.

It is noticeable in Table VII that considerably more bacterial rot occurred in the commercially handled than in the carefully cut lettuce. From what is known of the nature of this disease it is not likely that this form of decay can be spread as readily by bad harvesting methods as the drop or that it will spread from head to head during transit or holding periods, as does the organism that causes drop. The smaller amount of bacterial rot shown in Table VII is probably due primarily to greater care in grading out diseased heads at the

time of harvesting. Only a slight difference is recorded between the amount of bacterial rot in the precooled and nonprecooled shipments made in 1914–15, although the holding lots shown in Table IV indicated considerably less bacterial rot in the precooled series for the season of 1913–14. Whenever bacterial rot was present it was found to increase greatly after the lettuce was withdrawn from the car and held at a warm temperature.

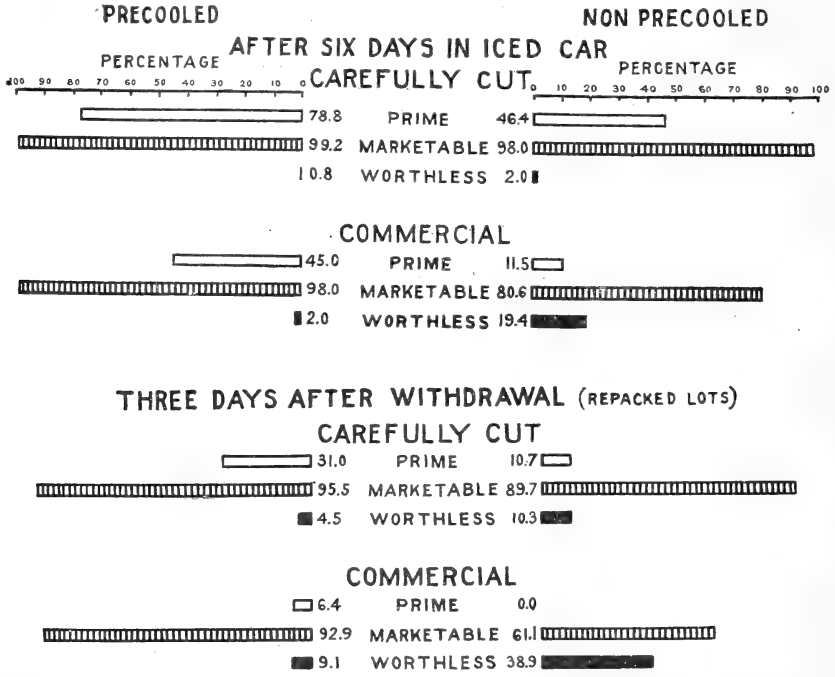

FIG. 12.—Diagram illustrating the percentages of prime, marketable, and worthless lettuce upon withdrawal from the car and three days later in precooled and in nonprecooled commercially cut and carefully cut lettuce held at Palmetto, Fla., season of 1914–15.

HOLDING LOTS.

In 1914–15 the holding lots were limited to seven complete series. Because of the shortness of the crop it was not always possible to secure enough carefully handled lettuce to provide for both holding and shipping lots. When this was the case, the holding lots were omitted.

Table VIII and figure 12 give a record of the market condition of the holding lots for 1914–15. A comparison of these results with those of the previous season, as shown in Table III and figure 8, gives a fairly good idea of the relative quality of the lettuce shipped during the two seasons. These two tables are comparable, because the lettuce in the holding lots was handled in the same manner during both seasons. The percentages of prime heads in all cases were greater in the 1913–14 lots. To some extent this may be due

to the fact that really first-class lettuce was very scarce in 1914–15 and that it was hard to classify small leafy heads as prime even though they showed no signs of decay. However, the inspections were made on as nearly the same basis as possible during both seasons. The percentages of marketable heads in the 1914–15 holding lots were fully as large, in general, as in the previous season. The effect of careful handling is clearly shown in Table VIII and figure 12. For the first inspection of the nonprecooled lots the average percentage of prime heads was 46.4 in the carefully handled lots and only 11.5 in the commercially handled lots, a fourfold difference in favor of careful handling. At the second inspection of the same lettuce

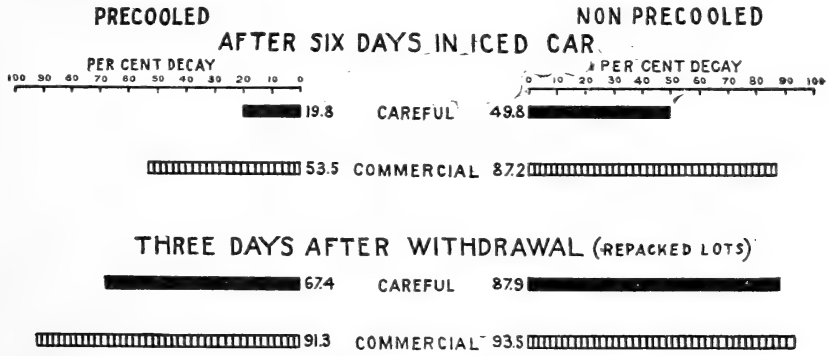

FIG. 13.—Diagram illustrating the percentages of drop decay upon withdrawal from the car and three days later in precooled and in nonprecooled commercially cut and carefully cut lettuce held at Palmetto, Fla., season of 1914–15.

made three days later, the carefully handled lots showed an average of 10.7 per cent of prime heads, whereas none of the commercially handled lots were of this grade. The effect of precooling is also very strikingly shown in these figures.

TABLE VIII.—*Average market condition of seven experimental lots of carefully cut and commercially cut lettuce held six days in an iced car at Palmetto, Fla., during the season of 1914–15.*

Treatment.	At withdrawal.		Three days after withdrawal.			
			Repacked.		Undisturbed.	
	Carefully cut.	Commercially cut.	Carefully cut.	Commercially cut.	Carefully cut.	Commercially cut.
Nonprecooled:						
Prime heads.....per cent..	46.4	11.5	10.7	0	15.9	1.1
Marketable heads.....do....	98	80.6	89.7	61.1	84.4	56.9
Precooled:						
Prime heads.....do....	78.8	45	31	6.4	23.3	3.9
Marketable heads.....do....	99.2	98	95.5	92.9	96.2	85

Table IX and figure 13 show the percentages of decay found in the lettuce held at Palmetto during the season of 1914–15. It is inter-

esting to compare Table IX with Table IV, which records a considerably lower percentage of decay for the season of 1913–14. In some cases the average percentages of decay in 1914–15 were several times greater than in 1913–14. For example, the nonprecooled carefully handled lettuce showed only 1.4 per cent of heads with bad drop-rot in 1913–14, whereas the following year the comparable lot showed 12.3 per cent.

TABLE IX.—*Average percentages of decay in seven experimental lots of carefully cut and commercially cut lettuce held six days in an iced car at Palmetto, Fla., during the season of 1914–15.*

Treatment.	At withdrawal.		Three days after withdrawal.			
			Repacked.		Undisturbed.	
	Carefully cut.	Commercially cut.	Carefully cut.	Commercially cut.	Carefully cut.	Commercially cut.
Nonprecooled:						
Heads showing slight drop-rot, per cent	37.5	45.2	47.6	22.2	40.3	19.4
Heads showing bad drop-rot, per cent	12.3	42	40.3	71.2	40.9	80
Total drop-rot [1] ....do....	49.8	87.2	87.9	93.4	81.2	99.4
Heads showing bacterial rot ....do....	.4	5.1	10.8	15.8	15	21.1
Precooled:						
Heads showing slight drop-rot ..do....	17.8	40.7	60 7	44.3	64.4	35.6
Heads showing bad drop-rot ....do....	2	12.8	6.7	47	8.3	45.2
Total drop-rot [1] ....do....	19.8	53.5	67.4	91.3	72.7	80.8
Heads showing bacterial rot ....do....	1.2	0	5.2	13.6	13.8	22.6

[1] In some cases both drop and bacterial decay were found on the same head. As these diseases were recorded separately the total of all forms of decay may appear to amount to more than 100 per cent in some instances.

In spite of the naturally inferior quality of the lettuce in 1914–15, the results of both the precooling and the handling work are very marked. The tables and diagrams will bear very close analysis, as they contain much more information than can be given in this brief discussion.

CELERY-HANDLING INVESTIGATIONS.

NATURE OF THE PROBLEM.

The celery-handling investigations were conducted at Manatee and Palmetto, Fla., mainly during the spring of 1915. At this season of the year high temperatures usually prevail in Florida and frequently occur throughout the North. When the celery is hauled from the fields to the car to be loaded, a temperature as high as 80° to 85° F. is by no means uncommon. The cars are loaded rapidly and the doors closed, confining all the heat within. It is manifestly impossible for the ice in the bunkers at either end of the car to reduce the heat to a safe temperature in as short a time as is desirable. As a matter of fact, the cooling that takes place in such a car is necessarily uneven

as well as slow. The crates generally are spaced an inch or two apart in order to facilitate the circulation of air, but even greater spacing would be by no means sufficient to equalize the rate of cooling throughout the car. The heavier cold air settles in the lower part of the car, and the entire lower layer therefore cools off rather quickly, though not as rapidly in the center as near the ice bunkers in each end. The upper layers, especially the top tier, cool off more slowly. This fact is particularly noticeable in cars that have been closed for only a few hours after being loaded. When the doors in these cars are opened the air near the floor feels cold, but that near the ceiling is often unbearably hot. This heat sometimes causes serious damage. The leaves turn light yellow, and as this injures the appearance of the celery and is recognized on the market as an indication of lessened vitality, crates containing celery with yellow tops are discounted accordingly. In general practice, when the car is unloaded the crates from the top of the load are purposely mixed with the more attractive crates of the lower tiers, in order to make them sell at a fair price. If the celery in the top crate is very yellow, however, the entire shipment is discounted 25 to 50 cents per crate below the price which it would have brought had there been no "yellow tops."

Celery from the Manatee section of Florida is shipped largely in crates 12 inches in depth. This is regarded as the standard crate in that section. In other localities, notably around Sanford, the 10-inch crate is the standard. The minimum freight rate is quoted on 350 crates regardless of size, and when the larger crate is used this number makes a load that reaches within 8 or 10 inches of the top of the car. Naturally, it is more difficult to lower the temperature in this car than in a car loaded with the 10-inch crates, where more space is left between the top of the crates and the roof of the car. In both cases, however, there is often serious damage due to slow cooling. In this connection, attention should be called to the desirability of the adoption by the growers of a standard-sized crate for all sections of the State.

OUTLINE OF CELERY-PRECOOLING EXPERIMENTS.

In order to determine the effect of precooling upon the temperature of the celery while in transit, two experimental cars were procured in March. Twelve electric thermometers were placed in various parts of the load in each car as in the case of the lettuce cars, and one of the cars was precooled. The bunkers of the precooled car then were topped off sufficiently to replace the ice that was lost by melting during the time it was being loaded and precooled, but no more ice was added during its entire trip. The other car was shipped in the usual manner, i. e., under full refrigeration. In

other words, this check car was topped off with ice after loading, and reiced in transit at the regular icing stations. A representative of the Department of Agriculture accompanied these cars and took accurate temperature records from time to time. The average temperature of the load in each car was computed from the 12 readings taken at each recording point.

TRANSIT TEMPERATURE RECORDS.

Figure 14 shows the average temperature of the celery in each car from the time it was loaded until it reached the market. The temperature of the outside air during the entire trip is shown also. The divisions at the left indicate degrees of temperature. The bottom divisions indicate the time in days. The small circles on each of the

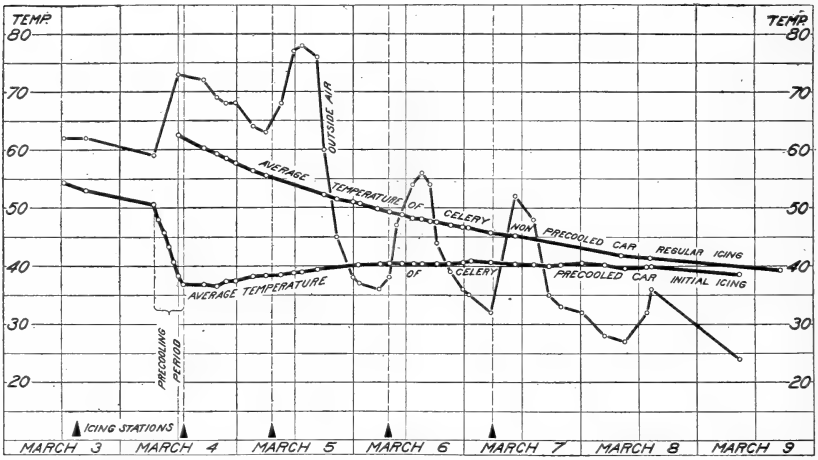

FIG. 14.—Diagram illustrating the average temperatures (° F.) of carloads of precooled and nonprecooled celery in transit from Florida to New York, season of 1915.

curves are placed at the intersection marking the time that the reading was made and the temperature at that time. The lower curve represents the temperature of the precooled car and the upper curve that of the nonprecooled car. The irregular curve running through the chart marks the outside air temperature.

The precooled car was loaded about noon on March 3, but was not cooled until the following morning, at which time the temperature of the car was only about 50° F. The first part of the curve illustrates this precooling period and shows the length of time required to precool the car and the temperature of the car at the time it was shipped. This point, about 37° F., was known to be lower than the ice would hold it, but as this was the first car shipped under initial icing it seemed desirable to be on the safe side by starting with a low temperature. The diagram shows very clearly how the temperature

crept slowly up to 41° F., and also how it remained at that point for almost two days in spite of large fluctuations in the outside temperature. It then began to drop below 40° F. again, owing to the cold outside temperature that the car encountered in the North.

The nonprecooled car was loaded on March 4 and started with a temperature of 62.5° F. It is interesting to note how very slowly the temperature of the celery in this car was lowered under the influence of ice alone. It was almost four days after leaving its starting point before it had reached as low a point as the precooled car maintained for the entire trip. It is during the first few days, as previously explained, that the damage by high temperatures is done. Subsequent cooling may prevent only further deterioration.

Figure 15 indicates the average temperature in the top and bottom tiers in both cars. It should be noted that during the entire trip the

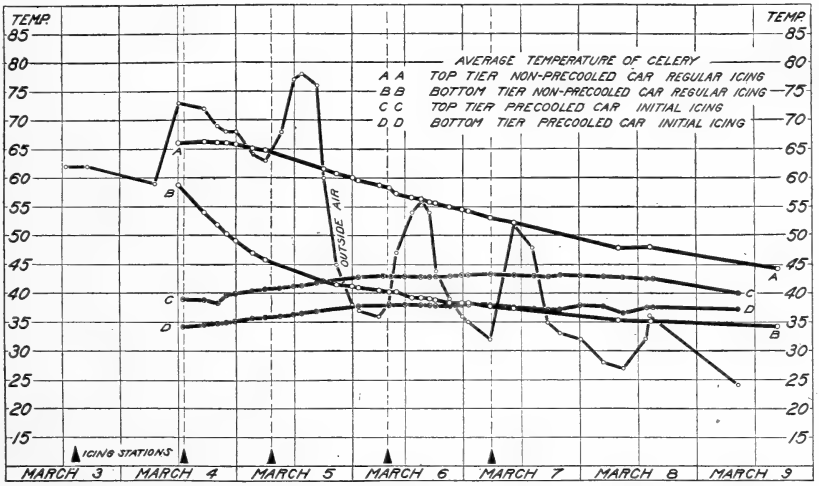

FIG. 15.—Diagram illustrating the average temperatures (° F.) of celery in the top and in the bottom layers of crates in carloads in transit from Florida to New York, season of 1915.

temperature of the top tier in the nonprecooled car was 10 degrees or more higher than the bottom tier. For a large part of the trip, the differences amounted to about 18 degrees. The precooled car, on the other hand, had only a difference of 5 or 6 degrees between the top and bottom tiers during the whole trip. The temperature in the bottom of the nonprecooled car went slightly below that of the precooled car after the third day, owing, no doubt, to the several reicings that it received in transit. The important point, however, is the fact that the temperature of the top tier in the nonprecooled car was far above that of the precooled car for the entire trip and even upon its arrival at its destination was still 5 degrees higher than the top tier of the precooled car. This seems to indicate that even after

five days in transit the field heat had not been removed from the upper part of the fully refrigerated car to the extent that it was removed from the precooled car at the time it left its starting point.

Figure 16 shows the maximum and minimum temperatures in both cars. Each point is the average of two thermometers placed in the same crate. One was inserted in the center of the crate and the other in the mass of leaves at the top. The minimum temperatures were obtained on the bottom tier next to the ice bunkers and the maximum temperatures were obtained on the top tier.

The maximum temperature in the nonprecooled car started at about 66° F. and rose during the first 18 hours to about 70° F. It then dropped slowly to a final temperature of 48° F. During the early part of the trip the difference between the highest and the

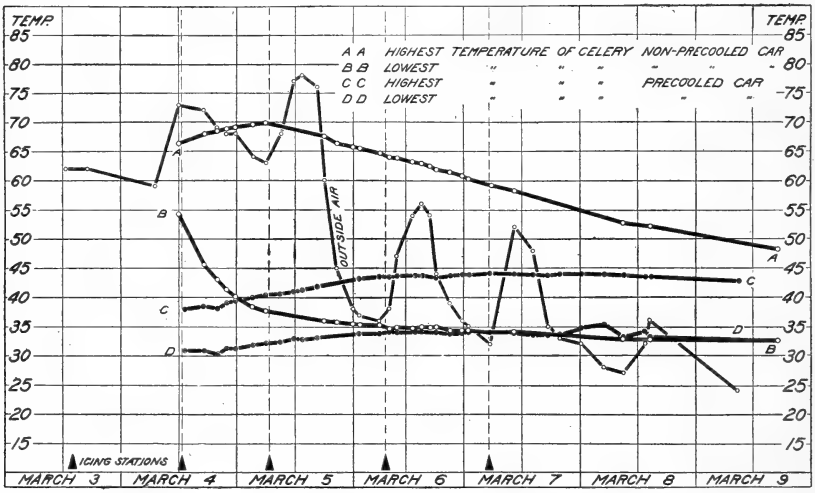

FIG. 16.—Diagram illustrating the highest and the lowest temperatures (° F.) of celery in carloads precooled and nonprecooled in transit from Florida to New York, season of 1915.

lowest temperature in the nonprecooled car was over 30 degrees, whereas in the precooled car the greatest difference was only about 10 degrees. If the precooled car had been iced in transit to make it comparable with the nonprecooled car, the difference in temperature between the top and bottom tiers would have been still less. As it was, the highest temperature in the precooled car was over 6 degrees lower than that of the nonprecooled car when it reached its destination.

The celery in the precooled car arrived on the market in fine condition. The leaves in the top crates were nearly as green as those in the bottom crates, and the receiver pronounced this car the best he had seen that season. The nonprecooled car arrived on the market showing the characteristic yellow leaves on the celery on the top tier.

COST OF PRECOOLING AND INITIAL ICING COMPARED WITH REGULAR ICING.

Attention must be called to the fact previously mentioned that the precooled car was handled under initial icing only. The charges on this car, aside from the regular transportation rate, were about $22 for ice, $7.50 special charge for the use of the car, ice tanks, etc., and $2 switching charges,[1] amounting to $31.50. In addition, the actual cost of precooling a car of celery is estimated at not more than $20.[2] This gives a total of $51.50 refrigeration charges on the precooled car. The full icing charge ordinarily paid amounts to $65. The experiment indicated, therefore, that by precooling and initial icing during the cooler weather not only better refrigeration could be obtained but also at a lower cost than by regular icing alone. The precooled car referred to arrived at its destination with the ice bunkers about one-third full. Two-thirds of the ice had melted, therefore, even during the comparatively cool weather in which it was shipped. Later shipments arrived on the market with very little ice remaining in the bunkers. To insure the best results in the warmest weather, it would seem advisable to reice the cars once while in transit.

OUTLINE OF CELERY-STORAGE EXPERIMENTS.

It was thought desirable to determine the effect of precooling not only upon the condition of the celery on its arrival at the market but also upon its storage qualities. Eight shipments therefore were made during the months of April and May, which mark the latter part of the celery-shipping season in Florida. Forty-eight experimental crates were included in each shipment. Half of these were in the precooled car and half in the nonprecooled car. Each lot was again divided, half being placed in the center of the car and half in the bunker end. Six crates from each of these lots were placed on the floor and six in the top layer. Thus the experimental crates in each shipment were exposed to the extremes of temperature in various parts of the car. All were shipped to New York City and upon arrival were placed in cold storage and held at a temperature of 32° F. An inspection of one-half of each shipment was made at the end of two weeks and of the remaining half at the end of four weeks.

STORAGE TROUBLES.

It was found that two serious diseases developed in the stored celery from Florida. These were designated as soft-rot and heart-rot. The soft-rot is somewhat similar in its development to the

[1] Precooling Tariff I. C. C. No. A3460.

[2] This estimate might be too low in the case of a small plant that is only run for a short time. In other cases probably it would be too high, as much depends upon the size of the precooling plant and the number of cars cooled.

lettuce drop and is said to be due to the same organism. Signs of it in storage are often first found on the leaves. It causes a soft, slimy decay that may consume the leaves entirely before seriously injuring the celery stalks. The disease causes the stalks to become discolored and watery and renders them unfit for consumption. Forms of this disease are encountered frequently in the field. The common foot-rot is said to be due to the same or a closely related organism.

Heart-rot is a term used to describe the darkening of the leaves and stalks forming the central bud or heart of the plant. This part first turns brown and later black, as the trouble develops. Heart-rot is found very often in the celery fields, especially late in the season. It appears to originate in the field, although some plants may have merely a predisposition to the disease at the time

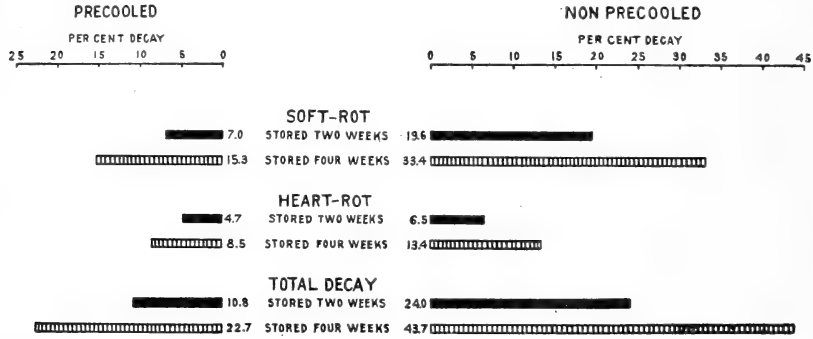

FIG. 17.—Diagram illustrating the percentages of soft-rot, heart-rot, and total decay at the end of two weeks and at the end of four weeks in storage at 32° F. in both precooled and nonprecooled celery shipped from Manatee, Fla., to New York, season of 1915.

they are cut and show no signs of it. It does not appear to spread to adjoining bunches in storage, but its development seems to bear some relation to the temperature to which it is exposed.

Leaf-spot also is a serious trouble, especially if celery is affected before being harvested. It frequently develops to an injurious extent in storage and is sometimes the cause of serious losses. Every effort should be made to control the leaf-spot and other diseases in the field through proper spraying and cultural practices. Celery entering storage in a diseased condition can not be held satisfactorily, even under the most favorable temperature and storage conditions.

RESULTS OF STORAGE EXPERIMENTS.

Summaries of the average results of the inspection of all the experimental lots of celery are given in the following tables and diagrams.

Table X and figure 17 show a comparison of the decay in the precooled and nonprecooled celery. The principal point brought out

by the diagram is the much smaller amount of soft-rot in the precooled than in the nonprecooled lot. In the celery stored for two weeks there was an average of 7 per cent of soft-rot in the precooled and 19.6 per cent in the nonprecooled, nearly three times as much in the latter case. At the end of four weeks the soft-rot in the precooled had more than doubled, but there was still twice as much in the nonprecooled celery. The amount of heart-rot also showed a consistent difference in favor of the precooled. The increase of

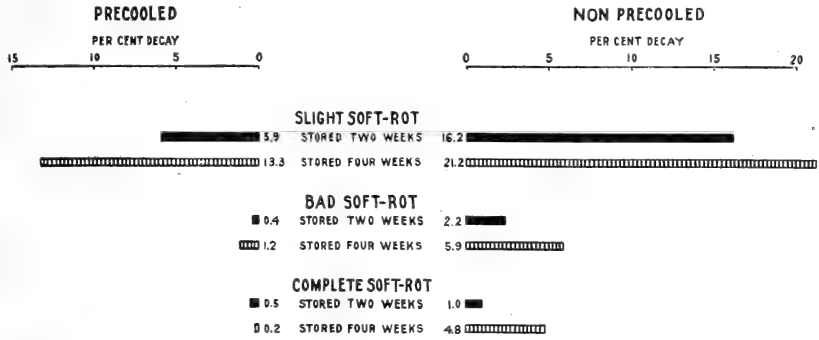

FIG. 18.—Diagram illustrating the percentages of slight, bad, and complete soft-rot at the end of two weeks and at the end of four weeks in storage at 32° F. in both precooled and nonprecooled celery shipped from Manatee, Fla., to New York, season of 1915.

heart-rot in the nonprecooled lots from 6.5 per cent at the end of two weeks to 13.4 per cent at the end of four weeks clearly shows that the trouble will develop in storage.

TABLE X.—*Average percentages of decay in storage of precooled and nonprecooled celery shipped from Florida, 1915.*

Disease.	Stored two weeks.		Stored four weeks.	
	Precooled.	Nonprecooled.	Precooled.	Nonprecooled.
Soft-rot.....per cent..	7	19.6	15.3	33.4
Heart-rot.....do....	4.7	6.5	8.5	13.4
Total decay [1].....do....	10.8	24	22.7	43.7

[1] In some cases both soft-rot and heart-rot were found in the same plant, but were recorded separately. Total decay refers to plants showing either or both forms.

Table XI and figure 18 show the various degrees of soft-rot at the different inspections. Celery was classified as having slight soft-rot if the decay was confined to not more than two or three stalks and bad soft-rot if the bunch showed considerable decay but still had a marketable "heart." "Complete soft-rot" was the term applied to the celery that was so badly decayed as to be rendered worthless. The diagram (fig. 18) shows that practically all the bad and complete soft-rot in the precooled celery was so slight as to

cause but little serious loss. The nonprecooled celery, on the other hand, showed considerable bad soft-rot and complete soft-rot. At the end of a 2-weeks' storage period the precooled showed less than one-half of 1 per cent of bad soft-rot in contrast to 2.2 per cent in the nonprecooled celery. Two weeks later there was still five times as much bad soft-rot in the nonprecooled as in the precooled. At the end of two weeks in storage the precooled celery showed 0.5 per cent and the nonprecooled 1.0 per cent of complete decay. At the last inspection the precooled celery showed 0.2 per cent and the nonprecooled 4.8 per cent, or at the end of the storage periods there was twenty times as much worthless celery in the nonprecooled as in the precooled lots. The slight inconsistency between the amount of complete decay at the end of two and four weeks is doubtless due to the comparatively small number of crates used in the experiment. The celery was discarded after the first inspection and a different lot of crates used in the final inspection.

TABLE XI.—*Percentages of slight, bad, and complete soft-rot in the storage of precooled and nonprecooled celery shipped from Florida, 1915.*

Disease.	Stored two weeks.		Stored four weeks.	
	Precooled.	Nonprecooled.	Precooled.	Nonprecooled.
Slight soft-rot.....per cent..	5.9	16.2	13.3	21.2
Bad soft-rot.....do....	.4	2.2	1.2	5.9
Complete soft-rot.....do....	.5	1	.2	4.8

The percentages in figure 18 clearly show the possibility of storing late Florida celery on the market from two to four weeks, especially if it has been precooled. Nonprecooled celery may reach the market in salable condition, but at this season of the year its storage is likely to be attended by serious loss, due to decay and to its decreased attractiveness. The practical applications of this may be found in storing celery at periods when prices are low or the market is temporarily overstocked. Celery then may be stored and held for a better price. A glance at the market reports will show how celery fluctuates at this season of the year, owing to weather conditions and the shipments from other sections. Toward the end of the shipping season, the storage of celery may help to bridge the interval between the close of the Florida shipping season and the opening of the season in the northern fields. However, this is done largely by shipments of celery from Bermuda.

Figure 19 shows the difference in the amount of decay that develops in celery carried on the floor of the car and that carried on the top tier. This is due, as previously suggested, to the much higher temperature in the top of the car. The difference applies to the pre-

cooled car as well as the nonprecooled, as the figures in Table XII prove, but it is much more marked in the nonprecooled car. In the precooled car, three times as much decay developed by the end of two weeks in the celery from the top tier as had developed in that from the bottom tier. In the nonprecooled car there was five times as much decay in the celery from the top tier as in that shipped on the floor. The decay in the celery shipped on the floor of the nonprecooled car was less than the average for the precooled car. This fact

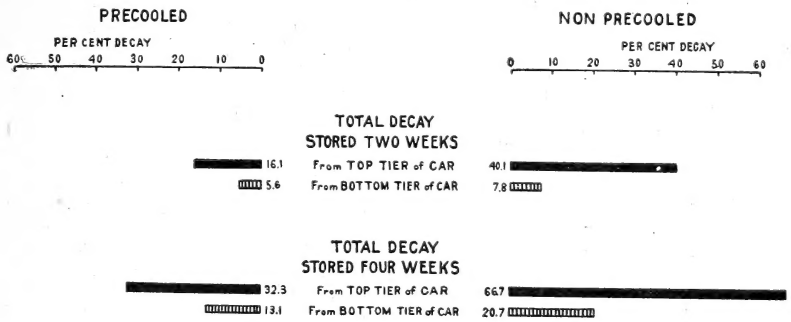

FIG. 19.—Diagram illustrating the percentages of decay at the end of two weeks and at the end of four weeks in storage at 32° F. in crates of celery from the top and from the bottom tiers in cars of both precooled and nonprecooled celery shipped from Manatee, Fla., to New York, season of 1915.

indicates that celery from the lower part of a nonprecooled car could be stored for this period with small loss. However, the upper tiers should be placed on the market as promptly as possible, to avoid excessive losses from decay.

TABLE XII.—*Percentages of decay in celery shipped in the top tier and the bottom tier in precooled and nonprecooled cars.*

Treatment.	Stored two weeks.		Stored four weeks.	
	Top tier.	Bottom tier.	Top tier.	Bottom tier.
Precooled.....per cent..	16.1	5.6	32.3	13.1
Nonprecooled.....do....	40.1	7.8	66.7	20.7

SUMMARY.

During the seasons of 1913–14 and 1914–15 investigations were conducted by the Bureau of Plant Industry for the purpose of ascertaining the causes of losses by decay in lettuce and celery shipped from Florida and to determine practicable means of reducing the same.

Decay in lettuce in transit was found to be due largely to lettuce drop, a disease which appears to enter the head mainly through the lower leaves.

Experimental heads of lettuce were cut just above the two or three lower leaves, and all diseased leaves were removed. This carefully cut lettuce developed far less decay in transit than the commercially cut lettuce.

Lettuce in cars that were precooled at the shipping point to a temperature of about 40° F. developed considerably less decay in transit than that shipped in nonprecooled cars.

The combination of careful cutting and precooling enabled the lettuce to reach its destination in almost perfect condition and to hold up much better on the market than lettuce handled in the usual manner.

Celery often is injured in transit because it is loaded too high in the cars to permit proper air circulation and rapid cooling. Smaller crates or a smaller number of crates in the load would help to insure more rapid cooling.

Temperature records taken in transit in a precooled, initially iced, and in a nonprecooled, fully iced celery car, showed that the nonprecooled took about four days to reach as low an average temperature as the precooled car maintained from the start.

During the entire trip from Florida to destination the temperature was never more than 5 or 6 degrees higher in the top tier than in the bottom tier of the precooled car, whereas in the nonprecooled car the difference amounted to 18 degrees for a considerable period.

The cost of precooling and initial icing of a car of celery was less than the usual charge for full refrigeration. In warm weather one icing in transit may be required, but probably this would not increase the cost above the usual full refrigeration charges.

Precooled celery arrived on the market in a uniformly fresh condition, with the leaves on the top tier nearly as green as those on the bottom. Nonprecooled celery showed very yellow leaves in the top tier. Such crates discount the value of the entire load.

During the latter part of the Florida celery-shipping season it appears that celery could be disposed of sometimes to better advantage if held in storage for a short period.

Precooled celery was stored successfully for four weeks with little decay, but stored nonprecooled celery developed considerable decay during the same period.

Celery from the lower part of a nonprecooled car can be stored for a short period, but during warm weather that on the top tier should be disposed of as soon as it reaches the market.

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